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Published in:
European Journal of Engineering Education

DOI (link to publication from Publisher):
10.1080/03043797.2020.1789070

Publication date:
2021

Document Version
Publisher's PDF, also known as Version of record

European Journal of Engineering Education

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/ceee20

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To cite this article: Anette Kolmos , Jette Egelund Holgaard & Nicolaj Riise Clausen (2021) Progression of student self-assessed learning outcomes in systemic PBL, European Journal of Engineering Education, 46:1, 67-89, DOI: 10.1080/03043797.2020.1789070

To link to this article: https://doi.org/10.1080/03043797.2020.1789070

Published online: 07 Jul 2020.

EUROPEAN JOURNAL OF ENGINEERING EDUCATION
2021, VOL. 46, NO. 1, 67–89
https://doi.org/10.1080/03043797.2020.1789070

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Progression of student self-assessed learning outcomes in systemic PBL

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ABSTRACT

Problem- and project-based learning (PBL) has been seen as one of the pedagogical models to bridge the knowledge gab between education and work. This article reports a study of students' preparedness from a systemic PBL university to enter work life. Theoretically, a conceptual understanding of a systemic PBL is presented including four elements: 1) knowledge and problem modes, 2) variation in problem and project approaches, 3) an interlinked full-scale curriculum, and 4) focus on PBL competences and employability skills. A longitudinal study for a national cohort of Danish engineering education students from the first-year programme until graduation and into their first job is presented. A comparison of a systemic PBL university with a reference group is presented. The findings show that students at the systemic PBL university compared to the reference universities report a higher level of preparedness in terms of generic and contextual competences but self-assess themselves as less prepared considering more domain-specific competences related to natural science.

ARTICLE HISTORY
Received 17 December 2019
Accepted 24 June 2020

KEYWORDS
PBL; systemic PBL; longitudinal study; students' learning outcomes

1. Introduction

Since the 90′s, employability and the gap between education and work have been on the societal agenda, and reports indicate the need to create bridges between work and education (Spinks, Silburn, and Birchall 2006; Lamb et al. 2010; Mourshed, Farell, and Barton 2012). Many of the studies on employability report on graduates' lack of relevant skills and competences and a need for higher education to change. Studies indicate that students expect their academic knowledge and competences to be of importance (Moreau and Leathwood 2006; Tymon 2013). Other studies emphasise the discrepancy between what academic staff and students view as important skills and what employers find relevant, and clearly there is a mismatch (Branine 2008).

However, there is no clear definition of employability skills. Markes (2006) carried out a review of the literature on employability skills in engineering and for each of the 22 studies reviewed, there is a separate list of specific employability skills. Across these studies, communication, teamwork, problem solving, and management seem to be the most dominant skills. Passow and Passow (2017) conducted a literature review on engineering skills and found that the coordination of multiple competencies is one of the most important competences, together with problem-solving, which makes sense as there will always be a need for more competences to solve given situations.

Therefore, the employability agenda is complex, and it is crucial to have a broad approach to avoid becoming too instrumental in the learning approach (Moreau and Leathwood 2006). In this article, a

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broad approach to employability has been applied, considering it as '*a set of achievements – skills, understanding and personal attributes – that makes graduates more likely to gain employment and be successful in their chosen occupation, which benefit themselves, the workforce, the community and the economy*' (Yorke 2004, 8). Furthermore, to understand employability in a more theoretical framework, Yorke identified four interlocking elements: understanding of the subject in relation to employability, skilful practice in context, efficacy beliefs, and metacognition (Yorke 2004). With this approach, Yorke (2004) links academic knowledge, skills, and personal and societal values, which gives a much more holistic view of the learner and the educated citizen. Employability is a question of having the competences to master a job and being aware of one's own role in society.

One of the major responses to employability in the engineering curriculum has been the application of project- and problem-based learning (PBL), which has been proposed as one of the solutions to bridging education and work in engineering education. Research indicates that an application of company projects in which students learn solve problems and experience a work environment increase employability (Stiwne & Jungert, 2010).

Reviewing the literature on PBL reveals that increased motivation for learning, decreased drop-out rates, and increased competence development are just three of the areas for which PBL has been mentioned as a solution in several studies (Dochy et al. 2003; Strobel and van Barneveld 2009). Similar studies on active learning, enquiry-based learning, design-based learning, and challenge-based learning show the same positive effect on learning outcomes (Prince 2004; Prince and Felder 2006; Roselli and Brophy 2006; Atman et al. 2007; Yadav et al. 2011). These results all indicate that when students are actively involved in decisions regarding their own learning process, it has a positive effect on the learning and also seems to increase knowledge retention (Norman and Schmidt 2000; Strobel and van Barneveld 2009). Despite criticism formulated by cognitive psychologists on the missing cognitive scaffolding in experiential pedagogy, more and more variations of PBL seem to be increasingly used with positive effects (Kirschner, Sweller, and Clark 2006).

Most often, the implementation of PBL is within a current university structure, which means within a single course (Thomas 2000; Hadgraft 2017; Kolmos 2017, 2017). In the field of engineering education, the literature from the 1990s and 2000s can generally be classified as the presentation of best practices, and there are a tremendous number of articles reporting on experiments performed in a single course or classroom followed by an evaluation of students' learning outcomes, all of which are reported to be increased (Popov 2003; Roselli and Brophy 2006; Ahern 2010; Nedic, Nafalski, and Machotka 2010; Gavin 2011). There are, however, more and more examples of programmes and universities that utilise the principles of PBL learning in various ways.

A recent review of PBL in engineering education show that the most common implementation of projects is within existing courses rather than across courses or at curriculum level (Chen, Kolmos, and Du 2020). The study reveals that the majority of the research reports single course project activities, whereas only a quarter of the papers report a more systemic approach to project activities across courses or at curriculum level. At course level, projects are mostly applied as means for students to deepen their understanding of the lectures and to enhance students' motivation for learning. The project types reported in the literature review are characterised by problems mostly given by teachers with few possibilities for the students to identify problems themselves with a duration of about a semester as long as the course is running, and with smaller teams of mostly three to eight students (Chen, Kolmos, and Du 2020). However, what importantly, there are a considerable amount of articles also reporting PBL at a more systemic level and this seems to be a trend.

In the USA, there are examples of institutional approaches like that of the Worcester Polytechnic Institute, which has practised project-based learning for quite some years; Olin College, a university that established a new active learning model with projects (Somerville et al. 2005; Grasso and Burkins 2010); Iron Range Engineering College, Minnesota, which changed to PBL at the institutional level (Ulseth and Johnson 2015); and the Massachusetts Institute of Technology (MIT), where New Engineering Education Transformation (NEET) is an elective thread throughout the curriculum. In Europe, there are examples such as University College London and the University of Twente, which have recently adopted a project-based model (Visscher-Voerman and Muller 2017), and the University College London, where 25% of students' time has been transformed to application to various types of projects in the curriculum (Mitchell and Rogers 2019). In Australia, there are several examples over time, of which the youngest are to be found at Swinburne University with a co-designed programme with industry, which developed a combined programme of internships and projects (Cook, Mann, and Daniel 2017), and Charles Stuart University, which developed a new programme that combines a virtual learning environment, internships, and project work, which is seen as an emerging change agent for engineering (Lindsay and Morgan 2016). There are many more initiatives and examples of institutional approaches from all over the world, indicating that the changes that have normally taken place at the course level are now also seen at a more systemic level

Research on change emphasises that the effect of PBL depends on the degree of system implementation (Thomas 2000; Graham 2012). If there are only changes at the course level and these are not coordinated at the overall curriculum level, there is a risk that the single courses will fall back to a traditional teaching mode. Therefore, a systemic level secures more sustainable development of a student-centred curriculum and the opportunity for students to obtain the added value of employability skills in various PBL practices.

1.1 Research question

Studies on PBL and employability indicate a positive impact on bridging the gap between education and work, and the PBL approach has proven its success. The PROCEED-2-Work study concludes that the Danish engineering students in the final semester from 2015 consider project work, especially projects together with companies, as one of the most important elements in the curriculum in their learning and preparedness for work (Kolmos and Holgaard 2017). Furthermore, a factor analysis on preparedness indicated that, compared to final-year students from other universities, final-year engineering students from systemic PBL engineering universities had a significantly higher self-assessment score on the factors 'society and environment' and 'business and organisation', whereas there was no significant difference concerning technical knowledge (Kolmos and Holgaard 2017; Kolmos and Koretke 2017). Recent research can therefore lead to the assumption that students from systemic universities are empowered throughout their studies to face increasing complexity in work environments, as they leave higher education with a self-perceived preparedness that represents a more comprehensive set of competences. In this study, the aim is to challenge this assumption and ask whether:

- the greater sense of preparedness of final-year students in systemic PBL universities has actually developed throughout the curriculum or whether these variations were already present during the first year?
- students from systemic PBL universities are empowered in regard to all types of competences – and if not, what are the blind spots to be aware of?
- the students' sense of preparedness when leaving a systemic PBL university is aligned with what they experience as important when they enter work life?

These questions call for a comparative study of the sense of progression in systemic PBL universities compared to other universities. Results from the findings can provide inspiration for future curriculum developments in how to empower students for employment. We use the notion of empowerment to underline that we study students' self-assessed preparedness.

A longitudinal study has been carried out following a national cohort of engineering education students from the first-year programme until graduation and into the first job. In this particular study, we compared the progression of the perceptions of engineering students from Aalborg University, Denmark, as a case of a systemic PBL university with those of engineering students from other Danish engineering universities. In the following, a conceptualisation of systemic PBL is presented together with a short case-presentation arguing for Aalborg University to be an extreme case of systemic PBL.

2. Systemic PBL curriculum – conceptual understanding

In order to analyse the data, it is necessary to have an understanding of what systemic PBL curriculum actually means. A curriculum is a component of an institutionalised system and there is a need for alignment with cultural, organisational, economic, and quality criteria to achieve an efficient outcome. The curriculum concept is understood as the frame for an entire programme instead of a syllabus for a course. The notion of a curriculum varies from an exclusive focus on the scientific content to a much broader approach on learning outcomes covering knowledge, skills, and competences, and from a focus on merely planning the formal curriculum to an inclusive focus on the total curriculum embracing the formal and informal aspects (Kelly 2009). That also means that the students' learning process and outcomes are in focus.

For a PBL curriculum, learning principles will be an important guide for all practices as they underpin the alternatives to a traditional academic curriculum. In the original versions of problem-based learning, project-based learning, and even enquiry-based learning, all share the same fundamental learning philosophy based on social constructivism, and at the level of learning principles it might be very hard to distinguish one pedagogical model from another (Marra et al. 2014). The fundamental learning philosophy is about stimulating students' curiosity for learning by identifying problems, analysing the problems in a broader contextual understanding, self-directed or participant-directed learning, team or group work, new teacher roles as facilitators, interdisciplinary approaches, and an emphasis on exemplary learning (Barrows and Tamblyn 1980; Barrows 1986; Algreen-Ussing and Fruensgaard 1992; Kolmos 1996).

A systemic PBL curriculum is likewise constituted with a common learning philosophy of student-centred pedagogy in which students learn through the identification and analysis of problems and experience of problem solving. Students learn cognitive strategies, generic skills, collaborative knowledge construction, and domain knowledge, and the PBL process can be organised as projects or cases. This approach embraces core ideas of learning and how to facilitate student learning as a participatory process or a co-construction process between academic staff and the students. The involvement of the students in defining the direction of the learning is a core idea in a PBL curriculum.

These core ideas, however, can be constructed in various ways and in the following we will elaborate on the criteria for systemic PBL in pointing out the distinction between this kind of PBL implementation and course based PBL-approaches, where as the latter might be present in almost any engineering education institution today. We will focus on defining four constituting elements of systemic PBL, that is: 1) an inclusive mix of knowledge and problem modes, 2) a variation of problem and project approach, 3) an interlinked curriculum, and 4) an explicit focus on PBL competences and employability skills in the curriculum.

2.1 An inclusive mix of different knowledge and problem modes

Engineering education has responded in various ways to the employability agenda. Jamison et al. (2014) identified three knowledge modes of a curriculum and corresponding learning approaches: academic mode, with an emphasis on theoretical knowledge; market-driven mode, with more focus on employability; and a community-driven mode, with a focus on civic society and sustainability. All the modes represent different academic values and approaches to the identification of problems and encompass the employability agenda and create various purposes of the curriculum. Barnett and Coate (2005) stress that the curriculum reflects the social contexts in which it is located and that various conceptualisations of curricula have been tacit parts of the educational landscape for some time, e.g. a curriculum can aim at outcomes, academic specialisation, reproducing current divisions in society, transforming higher education, serve as a market place for students or liberal education.

The variation in the curriculum is also reflected in the type of problems and projects students are working with. Savin-Baden (2000) identifies five modes which reflect a diverse practice and 1) PBL for epistemological competence, where knowledge is disciplinary with a narrow problem scenario. 2): PBL for professional action, where knowledge is practical and performance-oriented and the problems are from real life situations. 3) PBL for interdisciplinary understanding where knowledge is both disciplinary and contextual and the problem scenario illustrate a combination of theory and practice occurs. 4) PBL for trans-disciplinary learning, testing given knowledge and the problems are characterised by dilemmas of different kind. 5) PBL for critical contestability, where the learning outcomes are high level of critical thinking. These all represent different learning outcomes and respond to very different understandings of what a curriculum can be.

In the latest decades, engineering education has been faced with many different societal challenges that have required change in the curriculum, especially with emphasis on embracing more critical thinking and community-driven modes as there has been increased focus on human–technology interaction and on the impact of technology on cultural formations and ecosystems. The Grand Challenges and the UN Sustainable Development Goals (SDG) 2030 express in more detail the societal challenges, which are much broader than a traditional sustainability scope as they include perspectives on the 17 sustainability development goals (UNESCO 2017). Engineering education is of vital importance in addressing these challenges. The sustainability aspect is a major issue in engineering education for finding solutions to climate change and North/South relations and more broadly to reach the UN Sustainability Goals, and it calls for new types of universities with embedded social and civic values such as ecological universities (Barnett 2010). Furthermore, with the development of Artificial Intelligence and the Internet of Things, it will be important to develop new subdisciplines and interdisciplinary programmes that will move across to a hybrid academic mode (Schwab 2016).

From a curriculum perspective, all these challenges create tensions among theoretical academic knowledge and a reflective application of knowledge to analyse and solve the challenges embracing both market-driven interests and more community-driven concern for sustainable and society. This has implications regarding how to identify the problems with which students are working, as in many cases the problems have had a nature of purely academic or technical concern without relation to any of the contextual issues. In general, the pedagogical trends in engineering education have moved from teacher-driven to much more student-driven learning environments, and new student-centred learning methods have been applied in engineering education. Active learning, design-based learning, enquiry-based learning, the flipped classroom, case-based and problem-based learning, and problem- and project-based learning (PBL) as well as Conceive, Design, Implement, and Operate (CDIO) are just some of the educational practices that have become more commonly known. All these types of student-centred learning frameworks can address the relation between theory and practice as well as the dimensions of the practice relation between market-driven and community-driven considerations.

A variation and a balanced mix of the educational modes are needed in a systemic approach to PBL in engineering education, as basically all types of knowledge – theoretical, instrumental, and contextual – are needed to address the SDG challenges and to situate the engineering problems in the development, the production, the implementation, and the cultural appropriation of new and sustainable technological products and service systems.

2.2 A variation of problem and project approaches

The second criterion is the variation and combination of problems and projects. The notion of PBL is complex, and definitions in this field often originate from practice more than from theoretical frameworks. There is a huge variation in how to approach problems.

In the variation of organisation of the learning process with case-based PBL like in the medical field with academic staff crafting the problems. Students are working with project organised processes where students work on a common project which can be initiated by academic staff or students.

In engineering, there are a few examples of the case-based PBL approach, for example in chemical engineering (Woods 1996, 2000). However, most often PBL in engineering education is associated with project-based learning, which corresponds to the learning objectives for generic skills in engineering such as collaborative construction of knowledge, project management, leadership, and systemic understanding of technology. The degree of collaboration is more intense in a project-based learning environment as there is a common product in form of a project. In project-based PBL, students also identify problems starting from a theme or scenario, work jointly on analysing and solving problems, and submit a common product – normally a project report – and are usually assessed in groups.

Some scholars claim that engineering education has long used project-based learning – very often in laboratories and most often as individual projects. Kolmos (1996) operates with three types of project practices in engineering education: 1) a 'taskproject', which is a learning process directed by lectures; 2) a 'discipline project', which meets learning objectives within the discipline; and 3) a 'problem project', which is a process of identifying and solving open complex contextual problems. The task project is not really a project but an assignment in which the students just have to solve a teacher-formulated problem. Very often in engineering education, academic staff claim that they are already doing PBL when referring to this practice. Therefore, it is important to combine problem- and project-based learning to ensure that projects are unique and situated in a given context in which students have to identify open and complex problems and outline possible methodologies for solving them (Algreen-Ussing and Fruensgaard 1992).

The actual practices vary in terms of types of problems, types of projects, length of activities, combination of lectures and student work, progression throughout the course of study, assessment methods, teacher training, and institutional or course implementation, among other things (Felder et al. 2000; Prince 2004; Savin Baden and Howell 2004).

The varied combination of problem- and project-based learning is therefore seen as one of the characteristics of systemic PBL as it captures the fact that authentic engineering problems are typically so complex and contextually bound that students need to address them collectively and in an organised way. The underlining of variations indicates that students should experience several problem-and project-based learning experiences while following the curriculum and that it should be compulsory for students to participate in these activities.

2.3 An interlinked full-scale curriculum

Most traditional curricula consist of a set of well-defined courses of which a certain number are compulsory for enrolled students and the rest are electives which students can choose. Furthermore, there might be co-curricular activities which do not give formal credits but which students are motivated to choose.

Ruth Graham (Graham 2012), in her study on excellence in engineering education, found that the educational changes which were sustained were the ones with interlinked components in the curriculum. A change in a single course will be entirely dependent on a single teacher if it is not linked to some of the other elements in the curriculum. A recent review of PBL practices in engineering education indicated that around 70% of the selected journal articles in the review reported PBL at a course level, which indicates that most changes to PBL are limited to changes in single courses (Chen, Kolmos, and Du 2020).

An interlinked curriculum can be applied both horizontally in a single semester and vertically throughout the course of study. Progression does exist in most curricula, for example, sequential progression in mathematics. However, in an interlinked PBL curriculum, progression is between the subject courses and the project subject courses. This level implies a certain level of institutionalised practices (e.g. materialised through strategic or political announcements from the management), which yet again implies a certain degree of socialisation of PBL as a pedagogical approach (e.g. though staff training activities).

An interlinked PBL curriculum implies an organisational approach with learning outcomes that complement each other and with a progression from one semester to the next for the student-centred learning activities. Complementing elements can be used to link theory elements in one course to project-specific courses or can be a series of project-specific courses combined with industry collaboration and/or general theoretical courses. Furthermore, a progression in analysing and solving complicated to complex and interdisciplinary problems together with a variation in project size should be incorporated in the formal curriculum.

The CDIO society argues for an interlinked curriculum and is very systematic in describing principle standards, explaining the rationale behind the standards, and being explicit about the intended knowledge, skills, and attitudes by formulating a detailed syllabus as well as a rubric with six levels for each standard, ranging from 'no documented plan or activity' to 'provides a tool for self-evaluation' (see CDIO 2010).

A CDIO curriculum is organised around the disciplines and interwoven with project-based learning activities, in particular so called design–implement experiences. Crawley et al. (2014, 100) distinguish between three integration models of CDIO, which must be locally adapted:

- a block model integrating disciplinary content with personal and professional skills into one or more courses;
- a linked model where two or more subjects are taught separately and concurrently, eventually merging with CDIO skills and projects as the link;
- an umbrella integration model, where subjects are taught separately and are connected by some coordinating CDIO activity.

Furthermore, Crawley et al. (2014) draw attention to carefulness in the integration of the CDIO syllabus, to prevent repetition, introduction to a topic without ever really teaching it, or the expectation that students will utilise a topic without having been taught it.

An interlinked PBL curriculum might in many ways overlap with the CDIO approach; however, a full-scale implementation of PBL implies that all activities are planned with the aim of making students capable of working with authentic and rather complex problems by combining domain-specific and generic process competences. A full curriculum implementation of PBL allows a considerable part of students' time to be used on projects to address both complex contextual and open-ended problems on the one side and closed problems with a rather fixed solution on the other side, depending on the learning outcomes. Projects focusing on more closed problems are only considered as a way to deconstruct complexity for pedagogical purposes – making sense of the pieces which are later to be combined in a systems-thinking approach.

Thereby, in systemic PBL, PBL is integrated in the educational strategy and policy of the faculty as well as in the scope of all elements of the curriculum, which in a holistic way comes together and completes students' ability to identify and work with different types of problems, interact in and manage different types of projects, and more generally apply different knowledge modes to the problem at hand.

2.4 PBL competences and employability skills in the curriculum

The last element is the added value of PBL competences addressing employability. Research has indicated that there is an added value of PBL in terms of students learning employability skills although these have not been explicit learning outcomes and might not have been formulated in the formal curriculum (Dochy et al. 2003).

In the literature, there are many similar concepts representing more or less the same types of competences: employability skills, generic skills, transferable skills, core competences, twenty-first century skills, process competences, and so on. There are variations in the definitions of the skills, but basically these skills address the ability to apply one's academic knowledge in given situations, which will imply collaboration, management, learning, organisational understanding, problem identification and analysis, project management or entrepreneurship and so on. In the literature, PBL competences mentioned are very much like employability skills and the transfer of qualities from one situation to another or from one job situation to another. In the process of transfer, there is a meta-perspective in the sense that the learner is able to reflect on the outcomes from one situation, extract and conceptualise the meaning, and apply it in a new situation. This is also what is embedded in the competence concept from the European Qualification framework emphasising context dependency, complexity, and the ability to take responsibility for one's own learning at the competence level. Thereby, a meta-perspective is added to students' ability to optimise their employability skills through reflection and critical thinking and by combining past experiences and applying them to future and even more complex situations.

Having these types of competences formulated explicitly throughout the curriculum is a relatively new trend. In the CDIO and PBL systemic curricula, employability skills are an integrated part and are explicitly stated as learning objectives in the curriculum. However, whether or not the educational practices also have integrated reflection, progression, and assessment of these skills in reality is dependent on the implementation. Very few curricula have both a progression in the employability skills and a formal assessment of the progression across modules and semesters; in most cases, the employability skills are addressed in single courses.

But bringing transferable employability skills to the meta-level also implies a personal dimension. Twenty-first century skills embracing both aspects of PBL and employability skills will become even more important in the future as the concept of personal learning emerges as a new interpretation of lifelong learning. The personal learning approach addresses the individual learner's ability to create their own learning paths. This does not mean that learning becomes individualised but means that the individual creates his or her own learning path by participating in various learning communities and creating strategies for his or her own qualification development.

Thereby, systemic PBL focuses on PBL competences including employability skills, embracing a focus on reflection, critical thinking, and progression in the development of PBL competences in a way that will enable students to combine past experiences and apply them to future and even more complex situations. In systemic PBL, transferable competences are acknowledged in the curricula and in the assessment of students.

3. Research design

In order to study students' self-perceived competence level and work preparedness in systemic PBL compared to other less systemic approaches, we conducted a longitudinal study of all engineering students in Denmark who were enrolled in 2010. We followed this cohort by surveying them several times during their studies and we analysed the data comparing two groups of students from a systemic PBL university and from reference universities practising more randomly implemented PBL elements in courses.

3.1 Context of the study – systemic PBL university and reference universities

The PBL systemic university is founded on a PBL learning philosophy and the faculties are committed to a problem-based and project-organised model for all pedagogical activities. The principles of the pedagogical model have been explicitly formulated across faculties and include the following principles (Askehave et al. 2015):

1. The problem is the starting point for students' learning and students work with a variation of narrow and wicked problems throughout the curriculum;
2. Project organisation creates the framework for PBL;
3. Taught courses support the project work;

4. Collaboration is the driving force in problem-based project work;
5. The problem-based project work of the groups must be exemplary;
6. The students are responsible for their own learning achievements;
7. Students are assessed on their achievements of PBL competences.

As the PBL principles include all educational practices at the university, the principles manifest the systemic approach to PBL and a commitment from management to maintain a full-scale implementation. It is underlined (taking together principles 2 and 3) that PBL implies project work and that courses are seen as a means to ensure that students become familiar with a wide range of theories and methods which they can use in their project work.

In the engineering faculties, 50% of students' time is allocated to project modules. Semester projects, running in parallel with courses, make room for more comprehensive student-directed and team-based projects. To support student-directed learning in these team settings, students also have courses with an explicit focus on introducing PBL theories and methods for students to establish and develop their PBL competences in a professional way. In the engineering faculties at Aalborg University, all students therefore have one third of their course time in the first semester allocated specifically to PBL.

As a central core, there are learning objectives specifically related to problem design, as the ambition is that the process of identifying, analysing, and formulating a problem to be addressed in the project work will also be self-directed. As underlined in the PBL principles, a problem must be authentic and scientifically based. While authenticity implies that the problem is of relevance outside of academia, the demand for problems to be scientifically based implies that the scientific methods are used not only to solve the problem but also to analyse it. The PBL course therefore introduces students to different problem types and to different methods and theories for problem design. Another central core of the course is project management, including both structural and interpersonal competences. Last but not least, it is a central part of the course that students have to reflect on their learning experiences and experiment with new practices based on these reflections.

The reference group covers universities of which some also have a pedagogical affiliation by declaring membership of the CDIO society, and as mentioned in Section 2.3, the CDIO community also argues for an interlinked curriculum. However, none of these universities have a declared PBL perspective, nor are they based on a PBL philosophy where the identification and analysis of and solutions to authentic problems are seen as the means to and end of all learning activities. The universities might be systemic to a greater or lesser extent, depending on how the CDIO standards and syllabus are implemented. They might have single courses and even some projects integrating principles of PBL. However, for universities in the reference group, PBL activities are not mandatory and form a progression throughout the university. Students from reference universities might graduate with only one or two experiences working in project groups as the most common practice at the master level is an elective system, where student choose and sign up for courses. At a systemic PBL university the amount of experiences from projects will be incredibly higher, as there will be no choices to avoid projects and team work. This is the reason that the reference universities represent a course level PBL.

There is no doubt that there are PBL elements at the reference universities, but more at the course level than at the system level. Furthermore, the institutional implementation at programme level might vary from the formal intentions in the way that these principles are carried out. The potential differences at programme level are the reason for defining the universities as a gathered group of references and not as singular universities for comparable analyses and targeted recommendations.

The students entering Aalborg University do know that the university is practising a PBL model and in surveys they indicate that this is a reason to choosing the university. However, the at the same time, the majority of the students are coming from the region. The same counts for the reference universities.

4. Methods of the empirical study

This article presents findings from a longitudinal study carried out in the PROCEED and PROCEED-2-Work project from 2010 to 2016. This was a nationwide survey of all Danish students enrolling in engineering education in autumn 2010, and this cohort was surveyed in autumn 2010 (first-year students), spring 2011 (second-term first-year students), spring 2015 (final-year students), and summer 2016 (young graduates). In order to reduce the amount of data, the 2011 data have been excluded.

The PROCEED-2-Work took inspiration from the Academic Pathways of People Learning Engineering (APPLE) survey on specific questions and single variables (Atman et al. 2010; Sheppard et al. 2010). However, the survey was constructed with a view to Danish engineering education and Danish culture and therefore it has additional variables for the APPLE questions and the specific development of the 2010 survey is explained in detail in a previous publication (Haase 2014). Specific comparable studies between the US and Danish cohorts have been carried out for the 2010 data (Haase et al. 2013). In this article there is no comparison with APPLE data nor any application of the statistical analyses of the APPLE constructs.

Furthermore, the survey has questions on students' perceptions of competences, which have been inspired by Danish alumni studies (see Table 4). This questionnaire has been applied in several Danish alumni studies across the Danish universities and it was chosen to cross-validate the results from the APPLE-inspired questions in relation to the Danish context. Questions from this were only used for final-year students and young graduates.

Both questionnaires address employability for three out of the four areas as defined by York: as the understanding of the subject in relation to employability, skilful practice in context, efficacy beliefs, and metacognition (Yorke 2004). Questions have been chosen to address the first three points, whereas the fourth point on metacognition can hardly be studied by the application of quantitative oriented questionnaires. However, for the first three points, a series of variables of subject knowledge and employability skills like management skills, leadership, creativity, teamwork, and so on have been defined.

However, there are only a few questions which we were able to ask both first-and final-year students as well as young graduates (see Table 1). The first study in 2010 focuses on professional identity, engineering competences, sustainability, and societal challenges. For the 2015 final-year students and the 2016 study of young engineering graduates, not all the questions were applied and only the ones on professional identity and expectations and experiences regarding the transition from engineering education to work can be analysed for educational progression.

A limitation of the study is that we ask for students' perceptions and attitudes, which are often seen as some kind of weak data. However, we see the perceptions and attitudes as valid and core data for studying students' achievement of skills and competences. Perceptions and attitudes are a core part of the anticipation of the future and the feeling of preparedness, which influence choices and work approaches. As such, these data are an important part of a study on employability. We have, however, underlined that we use students' self-assessments by clarifying that the conclusions cover how different pedagogical models at the institutional level *empower* students for employment.

4.1 Population and sample

After piloting the instrument to test for item interpretation and understanding, the Danish survey was administered online in the first months after the students had entered their engineering studies. The survey was sent to all Danish engineering students in the eight engineering education universities, which offered 105 different engineering programmes in total. An overview of the survey data is presented in Table 2.

The cohort in 2010 comprised 3,969 respondents. Initially, all engineering students enrolling in any bachelor's degree in 2010 were included; however, in 2015 only students participating in the master's programme participated and additional students who enrolled in the master's-level programmes were added to the cohort.

Table 6. Students and graduates from PBL and reference universities on how important they thought each of the listed items was for becoming (students) a successful engineer or (graduates) successful at work.

How important do you think each of the following skills and abilities is for becoming a successful engineer (students) or successful at work (graduates)	First-year students					Final-year students					Young graduates				
	Mean		Standard Deviation		*P*-value	Mean		Standard Deviation		*P*-value	Mean		Standard Deviation		*P*-value
	PBL	REF	PBL	REF		PBL	REF	PBL	REF		PBL	REF	PBL	REF	
Self-confidence (social)	2.84	2.77	0.655	0.678	0.064 †	3.23	3.03	0.686	0.730	0.000 ***	3.43	3.37	0.581	0.602	0.400
Leadership ability	2.83	2.65	0.736	0.777	0.000 ***	2.61	2.50	0.834	0.797	0.041 *	2.63	2.63	0.798	0.734	0.971
Public-speaking ability	2.69	2.51	0.781	0.765	0.000 ***	2.84	2.72	0.810	0.823	0.026 *	2.94	2.77	0.706	0.706	0.029 *
Maths ability	3.15	3.19	0.682	0.674	0.300	2.72	2.97	0.846	0.803	0.000 ***	2.54	2.70	0.756	0.729	0.048 *
Science ability	3.19	3.25	0.652	0.622	0.144	2.93	3.13	0.814	0.750	0.000 ***	2.74	2.88	0.752	0.784	0.088 †
Communication skills	3.04	3.04	0.712	0.664	0.995	3.39	3.27	0.658	0.661	0.006 **	3.46	3.51	0.572	0.548	0.358
Ability to apply maths and science principles in solving real-world problems	3.46	3.54	0.617	0.632	0.025 *	3.23	3.48	0.843	0.688	0.000 ***	3.13	3.20	0.856	0.770	0.397
Business ability	2.34	2.23	0.768	0.743	0.019 *	2.50	2.27	0.904	0.811	0.000 ***	2.61	2.53	0.862	0.849	0.392
Ability to perform on a team	3.46	3.41	0.629	0.630	0.182	3.49	3.42	0.621	0.645	0.091 †	3.47	3.49	0.637	0.616	0.812
Critical-thinking skills	3.37	3.32	0.609	0.623	0.173	3.61	3.54	0.557	0.597	0.059 †	3.56	3.47	0.559	0.591	0.128
Desire to find new solutions	3.61	3.56	0.578	0.608	0.137	3.45	3.48	0.627	0.653	0.539	3.46	3.41	0.666	0.632	0.510
Ability to incorporate environmental impact						2.71	2.68	0.937	0.860	0.586	2.34	2.29	0.865	0.794	0.583
Social responsibility						2.65	2.51	0.909	0.834	0.013 *	2.42	2.28	0.814	0.826	0.117

N = first-year students: 1222–1252, final-year students: 1070–1075, young graduates: 357–363. † $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 1. Overview of questions and response group.

	First year	Final year	Young graduates
PROCEED: Please rate how well prepared you are to incorporate each of the following items while practising as an engineer.	x	x	
PROCEED: In your current employed position, how important is each of the following in your work?			x
PROCEED: How important do you think each of the following skills and abilities is to becoming a successful engineer (first and final years) or successful at work (young graduates)?	x	x	x
Alumni: To what extent do you believe you have acquired the following skills during your education?		x	

Table 2. Survey data.

	First-year students	Final-year students	Young graduates
Time of data collection	October 2010	May 2015	May 2016
Survey administration	Second month of their study. Sent out via emails collected from the eight universities	Penultimate month of their study. Sent out via emails collected from the eight universities	In principle, 11 months after graduation. Sent out via national identification numbers
Number of respondents	1304	1240	562
Men	76%	70%	70%
Women	24%	30%	30%
Response rate	33%	30%	12%

The response rate for the whole cohort was 33% in 2010, while it was 30% in 2015 and 12% in 2016. The respondents belong to the same cohort, but it might not be exactly the same respondents for all the three rounds of surveys. However, we have not been able to account for the number of students who dropped out between 2010 and 2015, and because of this, the response rate is systematically underestimated for 2015 and 2016.

In order to identify the influence of the curriculum on students' preparedness and valuation of engineering, the analysis in this article will focus on a comparison of the 2010 data collected just after enrolment, the 2015 data collected in the tenth semester just before graduation, and the 2016 data in which most of the respondents had been part of the work force for 10 months. The 2010 data are used as a baseline for the analysis, consisting of respondents' understanding of important engineering competences, expectations, and confidence in how ready they considered themselves to be for their first job; their view of and expectations regarding the transition; and their identification of elements of the curriculum that were central to their preparedness.

4.2 Analysis of data

The analyses of the data presented in this article are all based on a single approach: mean scores of scales and the results of independent sample t-tests are reported throughout. Levene's test for equality of variances is applied to check whether the compared populations have approximately the same amounts of variability between scores, allowing for adjustment in calculations in case they are not (Brown and Forsythe 1974; Schultz 1985)

Danish engineering students from three major universities were surveyed about a number of variables, and in this article, we look primarily at the students' ratings of how important a certain set of skills and abilities were in 2010, 2015, and 2016, when the students were respectively first-year students, final-year students, and young graduates. Another key variable is the students' ratings of how well prepared they felt to incorporate certain items while practising as engineers in 2010 and 2015. Obtaining some kind of compatible data from 2016 on this scale of preparedness was a challenge that was met by asking the graduates already working as engineers how important they thought each of the items was for their current position. The particular formulation about importance was chosen because of a consideration that engineers in their first year of work might not need to use the same set of skills or might not work with the particular set of items that they would later on. They would nonetheless have had an opportunity to observe which items were particularly important for their current work as well as for the positions they did not yet hold because of their roles as first-year employees.

5. Progression and blind spots – from first to final year of study

In the longitudinal study, the first-year (2010) and final-year (2015) students were asked how prepared they thought they were for engineering practice. The 2010 data create a baseline for the 2015 data in order to identify progress during the programme. Table 3 provides an overview of the results on students' self-reported preparedness considering the students in the systemic PBL university compared to the reference group.

5.1 The baseline for systemic PBL – low self-assessment scores for traditional engineering

The first-year students had just started their studies and only had two months of experience in engineering education. Therefore, the 2010 data primarily represent the students' prior expectations when

Table 3. Students from PBL and reference universities on how well prepared they were to incorporate the listed items while practising as engineers.

Please rate how well prepared you are to incorporate each of the following items while practising as an engineer	First-year students					Final-year students				
	Mean		Standard Deviation		*P*-value	Mean		Standard Deviation		*P*-value
	PBL	REF	PBL	REF		PBL	REF	PBL	REF	
Business knowledge	2.63	2.55	1.178	1.190	0.302	3.08	3.05	1.142	1.105	0.732
Communication	3.23	3.17	0.904	0.939	0.353	3.68	3.48	0.990	0.961	0.001 **
Conducting experiments	2.91	2.99	1.029	1.010	0.207	3.36	3.47	1.224	1.122	0.100 †
Contemporary issues	2.89	2.84	1.013	0.962	0.478	3.19	2.90	1.080	1.019	0.000 ***
Creativity	3.49	3.39	0.953	0.986	0.089 †	3.61	3.54	1.051	0.992	0.304
Data analysis	2.71	2.82	1.053	1.016	0.095 †	3.65	3.86	1.062	0.910	0.001 **
Design	2.71	2.67	1.088	1.067	0.619	3.24	3.08	1.197	1.150	0.039 *
Engineering analysis	2.40	2.67	1.072	1.006	0.000 ***	3.75	3.88	1.092	0.946	0.050 *
Engineering tools	2.49	2.77	1.069	0.990	0.000 ***	3.74	3.91	1.042	0.879	0.005 **
Ethics	2.85	2.88	1.082	1.147	0.669	3.22	3.13	1.183	1.146	0.199
Global context	2.75	2.71	1.057	1.046	0.563	3.13	3.05	1.190	1.063	0.280
Leadership	2.92	2.81	1.169	1.127	0.116	2.93	2.86	1.147	1.112	0.329
Lifelong learning	2.91	2.94	1.179	1.240	0.658	3.47	3.42	1.119	1.106	0.454
Management skills	2.90	2.86	1.032	1.037	0.532	3.30	3.19	1.122	1.016	0.087 †
Maths	3.30	3.39	0.991	0.976	0.179	3.34	3.75	1.257	0.974	0.000 ***
Problem solving	3.48	3.49	1.001	0.942	0.855	4.30	4.26	0.748	0.751	0.360
Professionalism	3.23	3.20	1.145	1.107	0.644	3.88	3.82	0.907	0.914	0.337
Science	3.05	3.23	0.984	0.966	0.003 **	3.69	3.84	1.001	0.849	0.013 *
Societal context	2.88	2.84	1.007	1.013	0.456	3.23	2.97	1.076	1.005	0.000 ***
Teamwork	3.74	3.68	1.001	0.968	0.374	4.42	4.13	0.733	0.808	0.000 ***
Environmental assessment						3.25	3.17	1.256	1.256	0.297
Social responsibility						3.36	3.19	1.178	1.178	0.017 *

N = first-year students: 1196–1208, final-year students: 1094–1104. † $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

choosing the engineering programme and having completed the introductory period of the programme.

As can be seen in Table 3, there are significant differences between the first-year students entering the systemic PBL university compared to the reference group, although there are only significant differences for 5 out of 20 items.

First year students entering the systemic PBL university felt significantly less prepared in terms of:

- engineering tools (M = 2.49, SD = 1.069) than the reference group (M = 2.77, SD = 0.990); $t(586)$ = 4.19, p = 0.000 ***
- engineering analysis (M = 2.40, SD = 1.072) than the reference group(M = 2.67, SD = 1.006); $t(1199)$ = 4.06, p = 0.000 ***
- science (M = 3.05, SD = 0.984) than the reference group (M = 3.23, SD = 0.966); $t(1198)$ = 2.94, p = 0.003 **
- data analysis (M = 2.71, SD = 1.053) than the reference group (M = 2.82, SD = 1.016); $t(1200)$ = 1.67, p = .095 †

This means that the students entering a systemic PBL university at the outset perceived themselves to be less prepared in terms of domain-specific engineering competences. Interestingly enough, the most significant differences were recorded in the two items specifically using the notion 'engineering'. Thus PBL universities should consider paying more attention to introducing students to the discourse of engineering.

For the more generic engineering competences like communication, problem solving, and teamwork there were no significant differences in the self-perception of preparedness when entering the universities. Only in one case were there significant differences in a generic competence, as first-year students entering the systemic PBL university had higher preparedness in terms of creativity (M = 3.49, SD = 0.953) than the reference group (M = 3.39, SD = 0.953), $t(1197)$ = −1.70, p = .089 †.

5.2 After being at a systemic PBL university – narrowing some gaps and increasing generic skills

If we move to data for students in their final year of study, Table 3 reveals far more significant differences between students being educated at the systemic PBL university and the reference group. There are significant differences in 13 out of 22 items, but there are no significant differences considering business knowledge, creativity, ethics, global context, leadership, lifelong learning, problem solving, professionalism, and environmental assessment.

The final-year students from the systemic PBL university had significantly greater preparedness in terms of:

- teamwork (M = 4.42, SD = 0.733) than the reference group (M = 4.13, SD = 0.808), $t(1098)$ = −5.91, p = .000 ***
- societal context (M = 3.23, SD = 1.076) than the reference group (M = 2.97, SD = 1.005), $t(798)$ = −3.93, p = .000 ***
- contemporary issues (M = 3.19, SD = 1.080) than the reference group (M = 2.90, SD = 1.019), $t(812)$ = −4.27, p = .000 ***
- communication (M = 3.68, SD = 0.990) than the reference group (M = 3.48, SD = 0.961), $t(1100)$ = −3.25, p = .001 **
- social responsibility (M = 3.36, SD = 1.178) than the reference group (M = 3.19, SD = 1.071), $t(787)$ = −2.38, p = .017 *
- design (M = 3.24, SD = 1.197) than the reference group (M = 3.08, SD = 1.150), $t(823)$ = −2.07, p = .039 *

- management skills ($M = 3.30$, $SD = 1.122$) than the reference group ($M = 3.19$, $SD = 1.016$), $t(783) = -1.71$, $p = .087$ †

Compared to the baseline study, the PBL final-year students therefore differ from the reference group in that significantly more of them feel prepared to incorporate generic competences while practising as engineers. Taking into consideration the substantial focus on collaborative learning in the systemic PBL case, having groups working in teams more than half of the time, it might not be surprising that students end up feeling more prepared regarding collaborative process competences like teamwork and communication. Furthermore, as they have far more experience with self-directed project work, a greater sense of preparedness regarding management skills could also be expected. It is however interesting to see that even the emphasis on contextual knowledge in PBL can be traced to an increased sense of preparedness regarding societal context, contemporary issues, and social responsibility all together. Last but not least, the increased sense of preparedness regarding design might be traced back to the comprehensiveness of the projects, where students themselves take ownership of the design of products and technological systems, which they later come to implement and test.

However, for the more domain-specific engineering and science skills, the indication from the baseline study repeated itself, as the final-year students from the systemic PBL university felt less prepared considering:

- maths ($M = 3.34$, $SD = 1.257$)than the reference group ($M = 3.75$, $SD = 0.974$), $t(692) = 5.61$, $p = .000$ *** (no significant difference when entering university)
- data analysis ($M = 3.65$, $SD = 1.062$) than the reference group ($M = 3.86$, $SD = 0.910$), $t(749) = 3.26$, $p = .001$ *** (†less significant difference when entering university, $p<0,1$)
- engineering tools ($M = 3.74$, $SD = 1.042$) than the reference group ($M = 3.91$, $SD = 0.879$), $t(738) = 2.79$, $p = .005$ ** (*** higher significant difference when entering university, $p<0,001$).
- science ($M = 3.69$, $SD = 1.001$) than the reference group ($M = 3.84$, $SD = 0.849$), $t(740) = 2.48$, $p = .013$ * (** higher significant difference when entering university, $p<0,001$).
- engineering analysis ($M = 3.75$, $SD = 1.092$) than the reference group($M = 3.88$, $SD = 0.946$), $t(749) = 1.97$, $p = .050$ * (*** higher significant difference when entering university, $p<0,001$)
- conducting experiments ($M = 3.36$, $SD = 1.224$) than the reference group($M = 3.47$, $SD = 1.122$), $t(1099) = 1.65$, $p = .100$ † (no significant difference when entering university)

Compared to the baseline, the difference from the reference group in terms of preparedness seem to decline in terms of science, engineering tools, and engineering analysis – in other words the gap has closed. However, in terms of maths, data analysis, and conducting experiments, students at the systemic PBL university seem to be less empowered than is the case for the reference group. Although a factor analysis in a more comprehensive study (Kolmos and Holgaard 2017; Kolmos and Koretke 2017) showed that there were no significant differences considering the technical competences taken all together and across more universities, it is still worth discussing whether systemic PBL universities should be more aware of pushing students to address problems, which would empower them more in terms of more traditional engineering competences, or whether systemic PBL universities should instead brand themselves on a more generic type of engineering.

5.3 Collaboration versus interdependence – a potential blind spot in systemic PBL

The results from a battery of questions (see Table 4), which is part of most Danish universities' alumni studies, further add to the finding that generic competences are emphasised in a systemic PBL university.

Table 4 shows that the final-year students from a systemic PBL university have a significantly stronger belief that they have acquired the following skills:

Table 4. The extent to which final-year students from PBL and reference universities believe they have acquired the listed skills during their education.

To what extent do you believe you have acquired the following skills during your education?	Mean		Standard Deviation		*P*-value
	PBL	REF	PBL	REF	
Theoretical knowledge within the field	3.64	3.72	0.585	0.511	0.042 *
Practical knowledge within the field	3.27	3.32	0.730	0.723	0.256
Relevant methodical skills in my field	3.42	3.43	0.644	0.633	0.696
Ability to handle complex issues	3.50	3.47	0.621	0.610	0.401
The ability to acquire new knowledge	3.73	3.74	0.523	0.486	0.661
The ability to cooperate within the field	3.59	3.56	0.619	0.606	0.379
The ability to work across disciplines	3.24	3.19	0.801	0.778	0.274
The ability to work with projects	3.84	3.62	0.436	0.593	0.000 ***
The ability to work in a structured way	3.47	3.42	0.668	0.694	0.227
The ability to meet deadlines	3.48	3.53	0.699	0.662	0.271
The ability to work independently	3.31	3.46	0.767	0.685	0.002 **
Communication and presentation skills	3.22	3.05	0.807	0.779	0.002 **
Project management	2.85	2.58	0.877	0.902	0.000 ***
Entrepreneurship	2.01	2.01	0.908	0.934	0.985
The ability to analyse and solve problems	3.58	3.55	0.625	0.588	0.428

N = 1003–1008. † $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

- the ability to work on projects ($M = 3.84$, $SD = 0.436$) compared to the reference group ($M = 3.62$, $SD = 0.593$), $t(940) = -6.59$, $p = .000$ ***
- project management ($M = 2.85$, $SD = 0.877$) compared to the reference group ($M = 2.58$, $SD = 0.902$), $t(793) = -4.70$, $p = .000$ ***
- communication and presentation skills ($M = 3.22$, $SD = 0.807$) compared to the reference group ($M = 3.05$, $SD = 0.779$), $t(756) = -3.09$, $p = .002$ **

On the other hand, the students from the systemic PBL university have a significantly weaker belief in having

- the ability to work independently ($M = 3.31$, $SD = 0.767$) than the reference group ($M = 3.46$, $SD = 0.685$), $t(707) = 3.14$, $p = .002$ ***
- acquired theoretical knowledge ($M = 3.64$, $SD = 0.585$) than the reference group ($M = 3.72$, $SD = 0.511$), $t(996) = 2.04$, $p = .042$ *

For other employability competences, such as the ability to work in a structured way and the ability to meet deadlines, there are no significant differences.

There is an alignment with the previously presented results regarding the significantly stronger belief in having obtained generic competences and the significantly weaker belief in having obtained theoretical knowledge among students from systemic PBL universities. However, the weaker belief in having the skills to work independently adds another dimension to the discussion of systemic PBL. Can there in fact be too much emphasis on teamwork and collaborative learning and too little emphasis on the individual learning processes? At least, these results raise the question of how to balance the concern for social and individual learning in systemic PBL.

6. Aligning the sense of preparedness with work experience

In the longitudinal study, the cohort was followed into their working life as so-called 'young graduates' in industry, where 'young' refers to the fact that these graduates had only been employed for about 11 months. In the following we will highlight the results addressing the students' sense of preparedness and the alignment with what they experienced as important when they entered working life.

Table 5. Responses of young graduates from PBL and reference universities regarding how important the listed items were for their jobs.

In your current employed position, how important is each of the following in your work?	Mean		Standard Deviation		*P*-value
	PBL	REF	PBL	REF	
Business knowledge	3.28	2.95	1.085	1.110	0.004 **
Communication	3.94	3.86	0.877	0.940	0.361
Conducting experiments	2.56	2.37	1.306	1.336	0.169
Contemporary issues	2.63	2.11	1.202	1.046	0.000 ***
Creativity	3.33	3.22	1.072	1.091	0.318
Data analysis	3.52	3.33	1.199	1.227	0.139
Design	2.88	2.95	1.285	1.187	0.594
Engineering analysis	3.10	3.36	1.120	1.220	0.034 *
Engineering tools	3.52	3.59	0.996	1.020	0.490
Ethics	3.01	2.72	1.277	1.220	0.022 *
Global context	2.85	2.72	1.313	1.227	0.322
Leadership	2.93	2.75	1.221	1.259	0.167
Lifelong learning	3.59	3.59	1.126	1.146	0.210
Management skills	3.46	3.05	0.970	0.994	0.000 ***
Maths	2.85	3.26	1.139	1.196	0.001 ***
Problem solving	4.26	4.25	0.763	0.832	0.985
Professionalism	3.98	3.90	0.854	0.956	0.418
Science	3.04	3.26	1.149	1.176	0.069 †
Societal context	2.79	2.35	1.198	1.067	0.000 ***
Teamwork	3.85	3.65	0.946	1.063	0.059 †
Environmental assessment	2.60	2.61	1.294	1.264	0.961
Social responsibility	2.87	2.56	1.193	1.156	0.013 *

Significance level assigned. N = 375–382. † $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

6.1 How a systemic PBL university profile is carried on to the workplace

As explained in the methodology section, the items presented in Table 3 and analysed in the previous section were used for a question posed to the cohort after graduation. However, the question was rephrased for the young graduates to consider how important the different abilities were in their current jobs.

Table 5 shows that considering their current employment, young graduates in industry from PBL universities assigned significantly more importance to:

- management skills ($M = 3.46$, $SD = 0.970$) than the reference group ($M = 3.05$, $SD = 0.994$), $t(374) = -3.95$, $p = .000$ ***
- societal context ($M = 2.79$, $SD = 1.198$) than the reference group ($M = 2.35$, $SD = 1.067$), $t(374) = -3.81$, $p = .000$ ***
- contemporary issues ($M = 2.63$, $SD = 1.202$) than the reference group ($M = 2.11$, $SD = 1.046$), $t(321) = -4.48$, $p = .000$ ***
- business knowledge ($M = 3.28$, $SD = 1.085$) than the reference group ($M = 2.95$, $SD = 2.110$), $t(380) = -2.87$, $p = .004$ **
- social responsibility ($M = 2.87$, $SD = 1.193$) than the reference group ($M = 2.56$, $SD = 1.156$), $t(374) = -2.49$, $p = .013$ *
- ethics ($M = 3.01$, $SD = 1.277$) than the reference group ($M = 2.72$, $SD = 1.220$), $t(380) = -2.29$, $p = .022$ *
- teamwork (M = 3.85, SD = 0.946) than the reference group (M = 3.65, SD = 1.063), t(362) = −1.90, $p = 0.059$ †

On the other hand, when considering their current employment, graduates from the systemic PBL university assigned significantly less importance to:

- maths (*M* = 2.85, *SD* = 1.139) than young graduates from the reference group (*M* = 3.26, *SD* = 1.196), *t*(374) = 3.35, *p* = .001 ***
- engineering analysis (*M* = 3.10, *SD* = 1.120) than young graduates from the reference group(*M* = 3.36, *SD* = 1.220), *t*(364) = 2.13, *p* = .034 *
- science (*M* = 3.04, *SD* = 1.149)than young graduates from the reference group(*M* = 3.26, *SD* = 1.176), *t*(374) = 1.83, *p* = .069 †

Comparing to the preparedness of the final-year students, these results indicate that the generated profile of the graduates from the systemic PBL university, which reveal them to be considerably more empowered in terms of generic competences and contextual knowledge. At the same time, items related to traditional and more fundamental subjects of engineering like maths, engineering analysis, and science seem to have significant less importance for the graduates from a systemic PBL university.

However, even though it seems that different educational profiles are mirrored in the job situation, there are also a lot of similarities when considering the graduates from the systemic PBL university and the reference group. There are for example no significant differences in the assigned importance for domain-specific competences such as data analysis, engineering tools, and conducting experiments or for generic competences like communication, creativity, leadership, problem solving, and lifelong learning. Furthermore, on considering the means, graduates from this comparative study seemed to agree that the top four most important items were: problem solving, professionalism, communication, and teamwork.

6.2 A rather aligned understanding of what matters in engineering when entering the workplace

Along the same lines, we asked what the respondents found important in engineering practice in general and therefore without direct reference to their current job situation. Table 6 shows the variables related to becoming a successful engineer from the first to the final year of study and finally when working in industry. In relation to previous questions, this adds to the study by showing the development in the cohort's conceptual understanding of what makes a successful engineer.

What is interesting when analysing the overview in Table 6 is that the number of significant differences in what were considered as important skills and abilities for becoming a successful engineer increased considerably during the stay at the educational universities – indicating that students were socialised into rather different perceptions of what matters in engineering. Then when students entered working life as young graduates, the significant differences seemed to vanish, and after 10 months of working in industry, there are only moderately significant differences with regard to 3 out of 13 items: public-speaking ability (*t*(360) = −2.19, *p* = .029*), maths ability (*t*(361) = 1.98, *p* = .048*), and science ability(*t*(361) = 1.71, *p* = .088†). Young graduates from systemic PBL universities assigned significantly less importance to maths (*M* = 2.54, *SD* = 0.756) than the reference group (*M* = 2.70, *SD* = 0.729), and the same was true for science ability (*M* = 2.74, *SD* = 0.752 compared to *M* = 2.88, *SD* = 0.784). On the other hand, young graduates from the systemic PBL university assigned a significantly higher importance to public-speaking ability (*M* = 2.94, *SD* = 0.706) than the reference group (*M* = 2.77, *SD* = 0.706). These differences in number and strength were however far lower than for final-year students, where significant differences were found in 11 out of 13 items.

If we look at the means and compare the final-year students with the young graduates, there is nevertheless an increase in the importance assigned to most generic competences for both cohorts when they enter working life. Thereby, on working, graduates increased the importance they assigned to the following generic competences: self-confidence, leadership ability, public speaking ability, communication skills, and business ability. For the more traditional and domain-specific competences, such as maths and science abilities as well as the ability to apply science and maths in solving real-life problems, the importance decreased when entering employment. These results corroborate other results from this longitudinal study (Kolmos, Holgaard, and Clausen 2018) and should lead to a discussion of how educational institutions can balance the educational profile with what, at least from this study, seems to be a broad conception of employability which includes an emphasis on generic competences.

7. Conclusion and final remarks

In this article, we question the assumption that students from a systemic PBL university are empowered throughout their study in terms of employability. We use the notion of empowerment to underline that we are studying students' self-assessed preparedness. Employability is viewed in its broadest sense as being for the benefit of the graduates, the workforce, and the community. Systemic PBL is viewed as an approach to PBL that enforces:

- a balanced mix of the educational modes combining basically all types of knowledge – theoretical, instrumental, and contextual – to address engineering problems in the development, the production, the implementation, and the application of new and sustainable technological products and service systems in different cultural contexts;
- a combination of problem- and project-based learning as it captures the fact that authentic engineering problems are typically so complex and contextually bound that students need to address them collectively and in an organised way;
- a full integration of PBL in the educational strategy and policy of the faculty as well as in the scope of all elements of the curriculum, which in a holistic way comes together and completes students' ability to identify and work with different types of problems, interact in and manage different types of projects, and more generally apply different knowledge modes to different problem types;
- an explicit focus on PBL competences including employability skills embracing a focus on reflection, critical thinking, and progression in the development of PBL competences in a way that will enable them to combine past experiences and apply them to future and even more complex situations.

With an interlinked curriculum that ensures a mix of different knowledge modes, systemic PBL ensures that students can approach a variety of problem types and project types and take into consideration not only the increased complexity of the problems that engineers face in current societies but also the more distributed and digitalised approaches to problem solving.

Aalborg University has been used as a case of a systemic PBL university, and through a longitudinal survey study, we have studied students' self-assessed preparedness in the systemic PBL institution compared to a reference group of comparable size and national context but without institutionalised systemic PBL.

We have analysed the data to see how the sense of preparedness of final-year students has developed throughout the curriculum or whether these variations were already present during the first year. The study clearly indicates that students at the systemic PBL university developed a greater sense of preparedness in terms of generic and contextual competences. However, the study also shows that students from the systemic PBL university assessed themselves as being less prepared than the reference group when considering more traditional and domain-specific competences related to natural science.

During the first year there are nearly no differences between the student approaches at the universities. It is again important to emphasise here that the main pool of students is recruited regionally. In that sense it seems that the pedagogical model do influence the students' self-assessment of what they are think they are confident in. Asking to the blind spots, we have to answer that there are blind spots in relation to the domain specific competences.

One can say that the students report what they have been exposed to. If the dominant content in engineering education is math, physics, and engineering tools, the students will feel much more confident in these areas than in e.g. generic skills like project management. If the content in engineering education – on the other hand – is dominated by learning scientific content by problem-solving in collaborative projects, the students will feel confident in the generic competences. This overall characteristic of students' educational profile is aligned with what they experienced as important when they entered working life. Furthermore, and as an additional finding, students from the systemic PBL university had a considerably lower belief in their ability to work independently than the reference group, which might be another blind spot.

However, the data did not only point in direction of employability belonging to a marked-driven university mode, but also social responsibility which belong to a more critical community driven mode. It seems that the students from systemic PBL university experience themselves more confident in sustainability and social responsibility, although there might not be more sustainability courses in the curriculum. An explanation might be that students in a PBL environment will experience to identify both technical and social problems.

This raises a discussion on the intended profile of a systemic PBL university and whether the emphasis on generic competences as well as collaborative skills can move too far. Likewise, a pending question is: what is the right balance of the knowledge modes for the future work situation as well as future societies? In this respect, the study does not provide such far-reaching answers – it however points to a trajectory for educational change. At least for the generic competences, this study shows that among the entire cohort the perceived importance assigned to generic competences increased when the young graduates entered employment, whereas the importance assigned to traditional and domain-specific competences decreased when they were actually working. So yes, a discussion is needed about the balance of different knowledge modes in systemic PBL, but if a broader employability profile is the ambition for engineers of the twenty-first century, systemic PBL presents a framework for educational transition that points in that direction.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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